protoDUNE Software Status & BNL Activity

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protoDUNE LArSoft Details

- protoDUNE code is part of dunetpc:
  - cdcvs.fnal.gov/redmine/projects/dunetpc
- Most code is common with DUNE FD
- When protoDUNE-specific details are required, this will be set via services fcl files
  - protoDUNE optical library generated by A. Himmel
  - protoDUNE cosmics library generated by M. Bass

```
protodune_services: {
  ExptGeoHelperInterface:        @local::dune_geometry_helper
  Geometry:                      @local::protodune_geo
  DetectorClocksService:         @local::dunefd_detectorclocks
  DetectorPropertiesService:     @local::dunefd_detproperties
  LArPropertiesService:          @local::dunefd_properties
  LArFFT:                        @local::dunefd_larfft
  DatabaseUtil:                  @local::dunefd_database
  BackTracker:                   @local::dunefd_backtracker
  SpaceCharge:                   @local::protodune_spacecharge
  LArSeedService:                @local::dune_seedservice
  SignalShapingServiceDUNE:      @local::dunefd_signalshapingservice
  ChannelStatusService:          @local::dunefd_channel_status
}

protodune_simulation_services: {
  LArFFT:                        @local::dunefd_larfft
  LArG4Parameters:               @local::protodune_largeantparameters
  ExptGeoHelperInterface:        @local::dune_geometry_helper
  Geometry:                      @local::protodune_geo
  DetectorClocksService:         @local::dunefd_detectorclocks
  DetectorPropertiesService:     @local::dunefd_detproperties
  LArPropertiesService:          @local::dunefd_properties
  DatabaseUtil:                  @local::dunefd_database
  LArVoxelCalculator:            @local::dunefd_larvoxelcalculator
  MagneticField:                 @local::no_mag
  BackTracker:                   @local::dunefd_backtracker
  SpaceCharge:                   @local::protodune_spacecharge
  LArSeedService:                @local::dune_seedservice
  SignalShapingServiceDUNE:      @local::dunefd_signalshapingservice
  PhotonVisibilityService:       @local::protodune_photonvisibilityservice
  OpDetResponseInterface:        @local::dunefd_opdetresponse
  ChannelStatusService:          @local::dunefd_channel_status
```

protoDUNE Geometry

- In gdml; includes wires and nowires version
- Developed by Martin Tzanov, starting from script generate DUNE FD gdml written by Tyler Alion
- Active volume and wire planes are correctly implemented with sufficient detail
- Basic cryostat volume implemented based on Martin's reading of engineering drawings
- Includes basic implementation of field cage (need work)
- Simple "beam window" implemented as nitrogen-filled steel pipe (needs work)
  - 25 cm outer diameter, 0.5 mm thick steel wall
  - Does not represent details of beam window design
  - Location somewhat arbitrary
  - Still some issues with particles interacting more tha expected
- Recently corrected material in outer volumes (foam, steel support) that affects cosmic simulations

Starting position for particle gun MC

Simple "beam window" (Yellow part penetrates foam, magenta part in LAr)
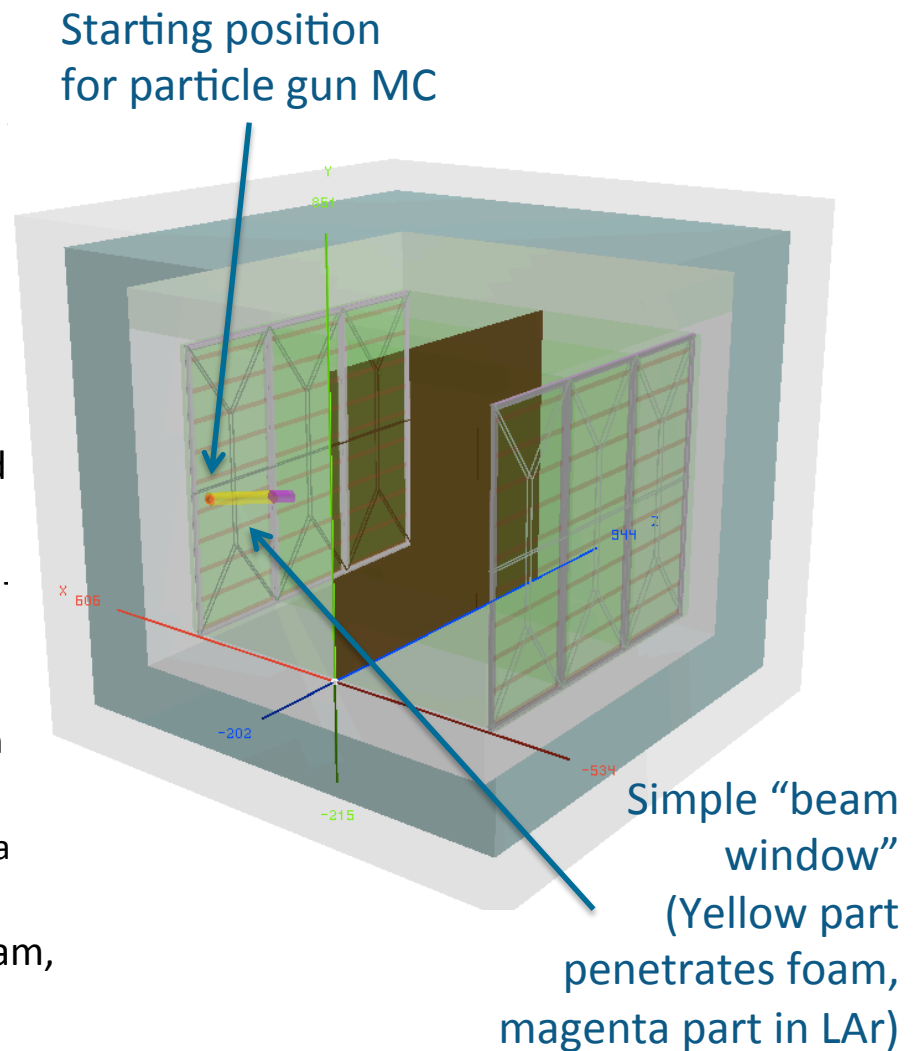
CORSIKA in LArSoft

- CORSIKA cosmic ray simulation implemented in LArSoft by Matt Bass
  - Originally for uBooNE
  - See talk at LArSoft coordination meeting: indico.fnal.gov/conferenceDisplay.py?confId=10893
- CorsikaGen module in LArSoft samples from pre-generated library of CORSIKA samples
- Data files containing pre-generated samples produced on per-experiment basis – thanks to Matt for generating this library for protoDUNE

CORSIKA

100 TeV p

- **CORSIKA** simulates extensive air showers initiated by cosmic ray particles
  - ○ Wide range of energy scales, multiple primary types (p, He, Fe, etc.)
  - ○ Resulting secondary particle flux evaluated at a specified altitude
  - ○ Multiple models available for interactions (GHEISHA, FLUKA, etc.)
- Past CR simulations for uboone have been with CRY
  - ○ Gives pre-generated distributions of particles at sea level, 2100 m, 11300 m based on tables from full MCNPX simulations of proton primaries between 1 GeV and 100 TeV
- CRY has a few shortcomings:
  - ○ FNAL (226 m) elevation not available, roughly 10% effect in muons
    - ■ Larger effect in neutrons, protons, and electrons
  - ○ Wide energy bins lead to binning artifacts in E,θ
  - ○ Only simulates proton primaries
  - ○ Limited to only using MCNPX model for particle propagation
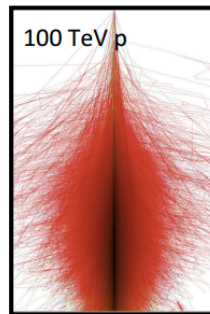
M. Bass[3]

Quick check of muon rates:
- uBooNE: ~160 Hz/m^2
- protoDUNE: ~170 Hz/m^2
- Expected difference based on altitude ~6%
- This exercise uncovered issues with material in outer layers of DUNE/protoDUNE geometry – fix in progress.

# Cosmic Simulation in protoDUNE

```
protodune_corsika_cmc:                     @local::standard_CORSIKAGen_CMC
protodune_corsika_cmc.SampleTime:       6.45e-3   #0.2 ms (g4 rise time) + 2.25 ms
 (1 full drift window) + 4.0 ms (readout)
protodune_corsika_cmc.TimeOffset:       -3.325e-3 #4.0 ms readout should start at
-0.875 ms to match data
protodune_corsika_cmc.BufferBox:        [ -300.0,300.0,-300.0,300.0,-300.0,300.0 ]
protodune_corsika_cmc.ShowerAreaExtension: 2000
protodune_corsika_cmc.ProjectToHeight:  865  #height to which particles are projected in cm
protodune_corsika_cmc.ShowerInputFiles: [
        "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT2*.db",
        "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT3*.db",
        "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT4*.db",
        "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT5*.db",
        "/pnfs/dune/persistent/users/mibass/corsika/sqShowers/DAT6*.db"
    ]
```

- SampleTime = 1 full drift time + readout window
- TimeOffset adjusted for protoDUNE readout window
- ProjectToHeight: Showers start here (just above the top of the cryostat volume in existing geometry because we do not have realistic simulation of building, etc)
- ShowerInputFiles: Files in dCache persistent

Example Cosmic "Event"

From Dorota:
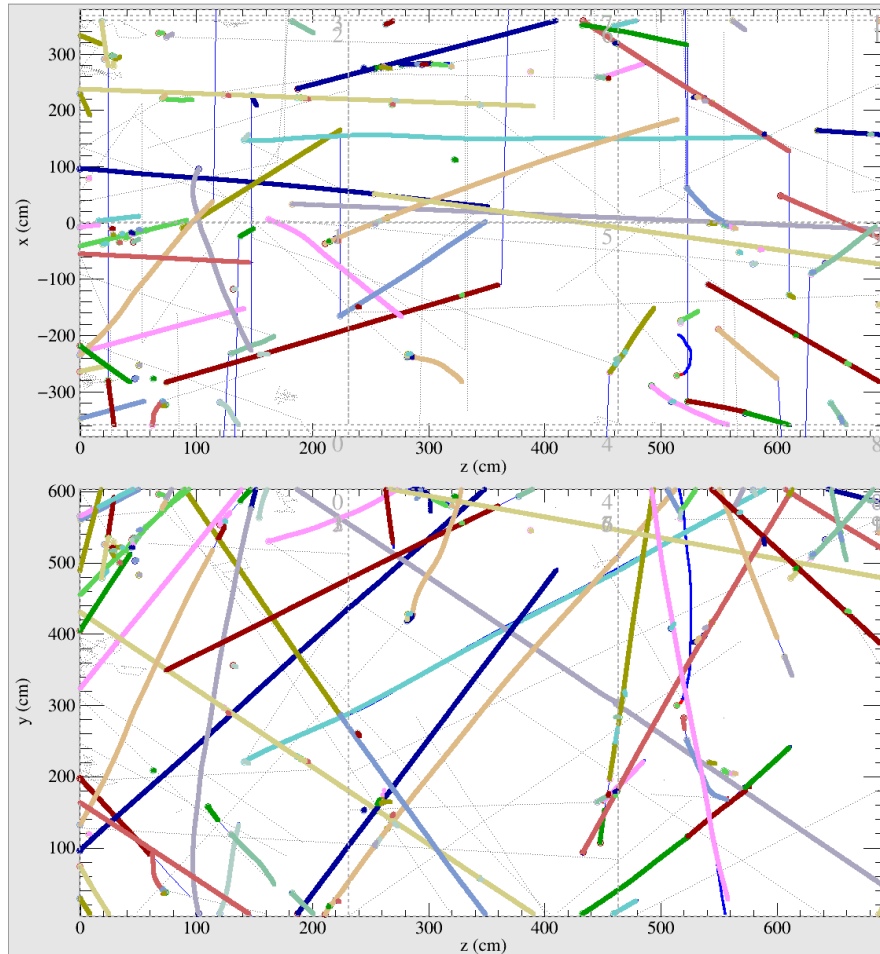
- Dorota reports reconstruction working well but Kevin sees tracks that are generated but not reconstructed – Dorota investigating
- Will have ~40 events per readout window

protoDUNE SCE Simulation

- M. Mooney has standalone code to calculate expected field distortion based on assumption of uniform space charge distribution

- Position distortions based on calculated variation in E-field implemented in LArSoft (LArG4/LArVoxelReadout)

- Adjustment to E-field used to calculate recombination factor in process of being implemented in LArSoft (LArG4/ IonizationAndScintillation)
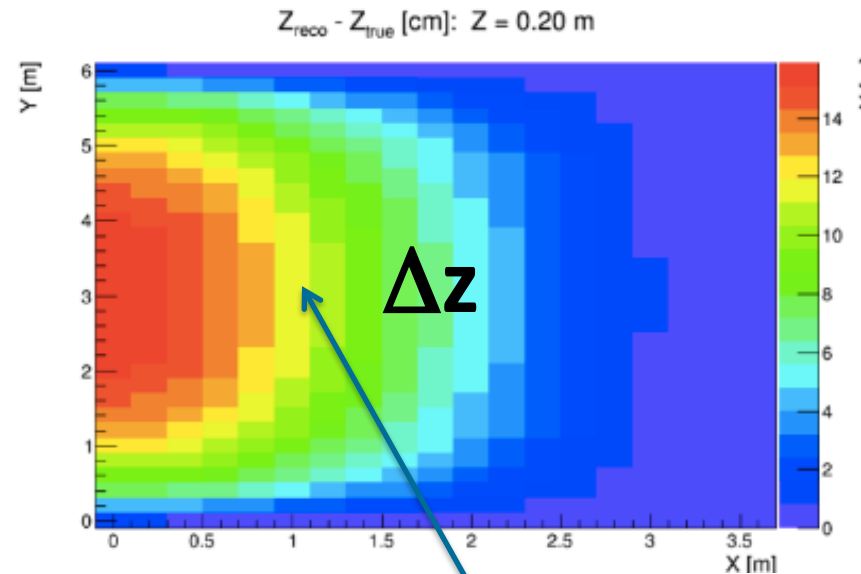

Typical location of particle gun particles in current geometry

protoDUNE SCE Calibration

- No laser calibration system planned for protoDUNE
- Cosmic tagger (using spare DC outer veto modules) being discussed
- Mike, Elizabeth, Flavio have been thinking about how to calibrate using cosmic and beam halo muons and requirements for cosmic tagger for this application
- See talks from Jacob and Mike in: https://indico.fnal.gov/conferenceDisplay.py?confId=12584

protoDUNE SCE Calibration
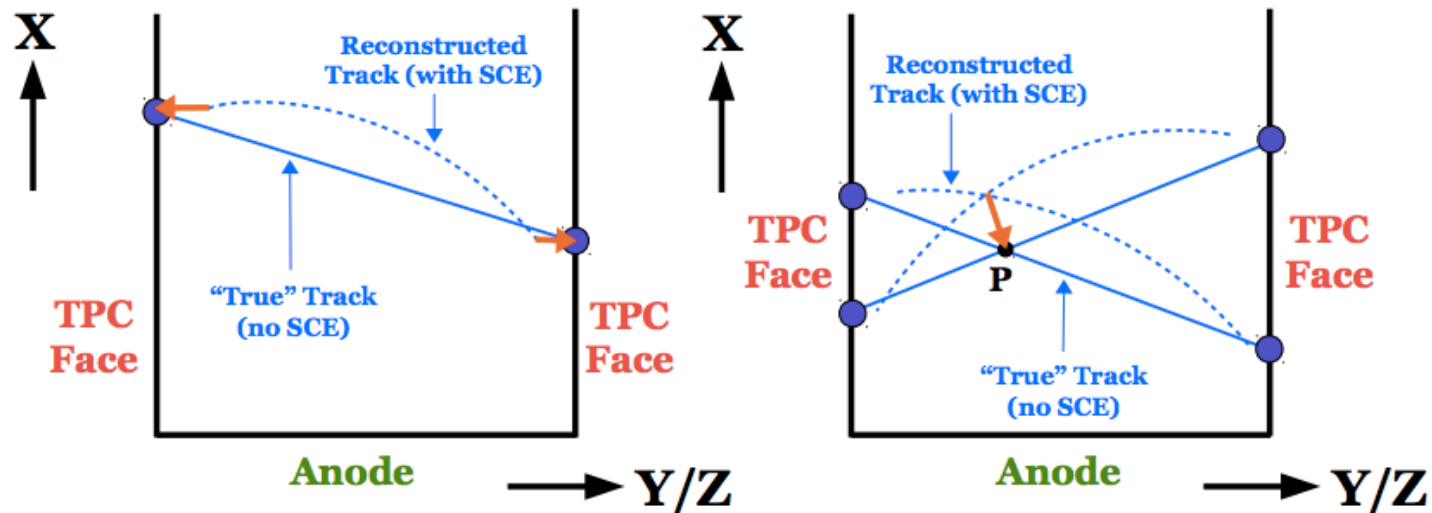
- ◆ Two samples of t_o-tagged tracks can provide SCE corrections:
  - Single tracks – enable corrections at TPC faces by utilizing endpoints of tracks (correction vector approximately orthonormal to TPC face)
  - Pairs of tracks – enables corrections in TPC bulk by utilizing unambiguous point-to-point correction looking at track crossing points
- ◆ Require high-momentum tracks (plenty from cosmics, beam halo) 5

protoDUNE SCE Calibration

- Elizabeth's summer student (Jacob) did simple study of illumination of cosmic tracks crossing a uniform distribution of beam halo tracks to see if top cosmic tagger required
- Using Jacob's framework, Matt is updating the study to include:
  - Higher statistics cosmic sample
  - Real beam halo distribution obtained from CERN beam simulation
  - Cosmic-cosmic crossing tracks
  - Cosmic tracks that cross APA-APA or APA-CPA
  - More realistic CRT geometry
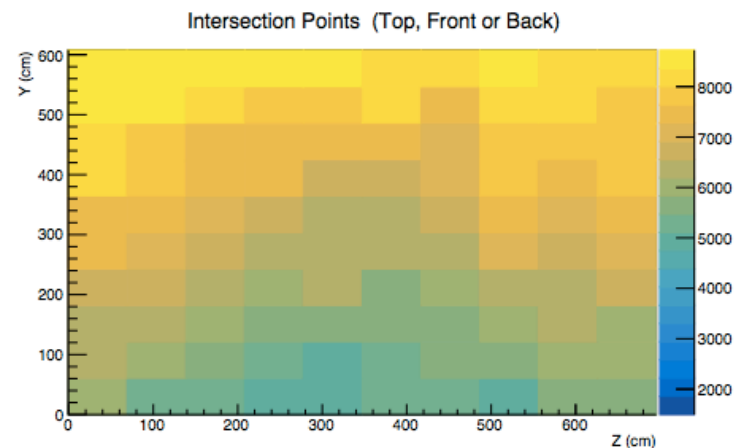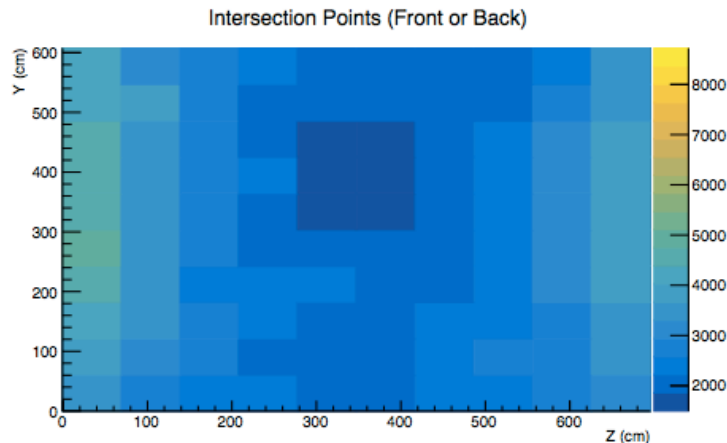
protoDUNE SCE Calibration: Outstanding Issues

- Time dependence (argon flow effects?)

- Required granularity of correction?

- Simplifying assumptions about size of effect at TPC edges ok?

- Optimal placement of CRT panels?

- Technical details regarding CRT panels

Existing MC Samples

- MCC6 samples:
  - No SCE
  - Particle gun injected at front face of "beam window"
  - Both mono-energetic and Δp/p-5%
  - Positrons (1 GeV)
  - Kaons (1 GeV)
  - Protons (1 GeV)
  - Pions (200 MeV)
  - Muons (200 MeV)
  - Samples chosen based on needs of reconstruction effort (Robert/ Dorota) and to for first exercise of MCC machinery with protoDUNE

- Privately generated samples:
  - Mono-energetic MCC samples with SCE position effect
  - Additional particle momenta using mono-energetic MCC setup w/ and w/o SCE position effect (BNL summer students J. Larkin and A. Depoian)
    - Positrons (300 MeV, 500 MeV, 1 GeV, 5 GeV)
    - Protons (700 GeV, 1 GeV, 2 GeV, 3 GeV)
    - Pions (300 MeV, 500 MeV, 1 GeV, 5 GeV)
    - Muons (500 MeV, 1 GeV, 5 GeV)
  - Cosmics ray sample (alone and overlaid on "beam" muons

All samples stored on FNAL DUNE disks (/dune/data or /pnfs/dune/scratch). Please contact Elizabeth for locations. Additional samples easily available upon request.

Work List

- Work list for both calibration and analysis topics generated at Science Workshop
- See email from Chang Kee or https://docs.google.com/spreadsheets/d/1qPS5ZwaDtyrMM8GfMvcwoQjyKksz_urL4OMCYYh6yMA/edit
- ETW listed as working on cosmic reconstruction, MM listed as working on space charge calibration
- All topics could benefit from additional effort

Meetings/Mailing Lists

- protoDUNE measurements group and DUNE calibrations group having joint meetings Thursdays at 10 CT.
  - Measurements meeting nominally in physics weeks, coordinated by Jarek Nowak and Donna Naples, meeting announcements go to fd-cernprototype@fnal.gov and CENF-LBNF-Test@cern.ch lists
  - Calibrations meeting nominally in detector weeks, coordinated by Josh Klein, meeting announcements go to dune-fd-calibrations@fnal.gov list